may be found in abundance on the branches of the sycamore, and on almost every leaf. In addition to eating the pustules of sycamore blight (*Gnomonia veneta*), they attack the leaf tissue, especially the midrib, where they chew out holes and sections which disfigure the leaves, and leave scars by which diseases may enter. After feeding, the adults oviposit in the stems, which have been newly killed by the blight. *Leiopus alpha* Say[1] mentioned in connection with *O. myrmex* is found in the adult stage at the same time. It confines itself to the dead and dying stems where it feeds exclusively on the blight pustules.

Magdalis pandura Say. Linglestown, Pa., June 14. Lemoyne, Pa. Reared May 3 from walnut—Kirk and Champlain.

Cylindrocopturus binotatus (Lec.) This species is very common at Harrisburg, Pa. It attacks weakened and possibly healthy staghorn sumac (*Rhus hirta*). It seems to prefer trees that have reached maturity and breeds in the sapwood on the main stem and branches.

Apteromechus ferratus (Say). Inglenook, Pa. Breeds in outer corky bark of sassafras, and does considerable damage; in fact, there was evidence enough to show that many trees had been killed. Adults emerge during July. Larvae in outer bark and sapwood.

STUDIES ON THE TAXONOMY AND BIOLOGY OF THE TARSONEMID MITES, TOGETHER WITH A NOTE ON THE TRANSFORMATIONS OF ACARAPIS (TARSONEMUS) WOODI RENNIE. (ACARINA)

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In the last few years frequent inquiries have been received from American entomologists in regard to the identity and habits of the Tarsonemid Mites. In response to these it has been found necessary to do some research upon these interesting and economically important acarids. It was thought at one time advisable to work out a synopsis of the American species or possibly even a monograph of them. A more serious reflection, however, showed that such an attempt at this time would be premature and ill-advised. Hence, in response largely to these inquiries I am here presenting certain additions to our knowledge of the Tarsonemid mites.

The Classification of the Tarsonemid Mites.

For many years all the species of this group were included in a single family, the Tarsonemidae. In my classification of the families and higher groups of the Acarina[1] in 1913 two families were recognized. To these should be added the family Disparipedidae of Paoli; and the long recognized and peculiarly degenerate genus *Podapolipus* of Rovelli and Grassi certainly should be accredited with family rank. The most of the genera and these four suggested families are arranged as follows, the more generalized groups being given first:

[1]Ewing, H. E. New Acarina, Part 1 etc. Bul. Am. Mus. Nat. Hist., Vol. xxxii, pp. 93–121, text figs. 1–9, Pls. vii–viii.

THE CLASSIFICATION OF THE FAMILIES AND GENERA OF TARSONEMOIDEA.

A. Both sexes provided with four pairs of funtional legs.

B. Females with elongate bodies; capitulum and first two pairs of legs not covered by any projecting cephalothoracic shield.

C. Posterior legs of female each ending in a pair of claws and caruncle. Species usually ovoviviparous.....*Pediculoididae.*

D. Female with a large capitulum, showing a rostrum and rudimentary palpi; segments of abdomen distinct.

E. Larval stage represented by octopod deutovum stage; gravid female with only the tip of abdominal wall swollen .....*Pediculoides* Tar.-Tpz.

EE. Larval stage normal; most of the dorsal wall of abdomen distended in gravid female.....*Pediculopsis* Reuter.

DD. Female with capitulum reduced to a cephalic papilla, and abdomen indistinctly segmented.....*Pigmephorus* Kram.

CC. Posterior legs of female devoid of claws and caruncle. Species oviparous.....*Tarsonemidae.*

D. Female with pseudostigmatic organs and very slender posterior pair of legs, which in the male are somewhat enlarged .....*Tarsonemus* C. & F.

DD. Female without pseudostigmatic organs and with short, stumpy fourth pair of legs, which in the male are reduced. .....*Acarapis* Hirst.

BB. Females with subdiscoidal bodies; capitulum and first two pairs of legs covered by the projecting cephalothoracic shield.....*Disparipedidae.*

C. Females with posterior legs each composed of five segments and provided with a pair of claws and caruncle.

D. Anterior legs of female each provided with a claw.

E. Segments IV and V of leg IV of female exceedingly slender, cylindrical and subcapillary.....*Imparipes* Berl.

EE. Segments IV and V of leg IV of female short, stout, and V never cylindrical.....*Pygmodispus* Paoli.

DD. Anterior legs of female clawless.....*Diversipes* Berl.

CC. Females with leg IV composed of four segments and without claws and caruncle.

D. Anterior legs of female each provided with a claw .....*Disparipes* Mich.

DD. Anterior legs of female clawless.....*Variatipes* Paoli.

AA. Males hexapod; females in their final stage legless.....*Podapolipidae.*

Contains the singular, degenerate genus.....*Podapolipus* Rov. & Gr.

The best known and probably the most important economically of all the genera of the Tarsonemoidea is the genus *Tarsonemus.* The females in this genus are so nearly alike that no specific characters for their separation have yet been found. The males, however, can be easily distinguished. A key is here given to the males of eleven species:

KEY TO MALES OF TARSONEMUS.

A. Posterior legs with hyaline leaf-like expansions.

B. Each hyaline expansion arising from inner central aspect of large second segment of leg.....*T. spirifex* Mar.

BB. Each hyaline expansion arising from inner distal aspect of large second segment of leg.

C. Second segment of leg IV swollen externally near its base.

D. Large latero-ventral spine of second segment of leg IV situated near the middle of segment.....*T. kirchneri* (Kr.).

DD. Large latero-ventral spine of second segment of leg IV situated almost at distal end of segment.....*T. pallidus* Bks.

CC. Second segment of leg IV not swollen near base.*T. spinipes* Hirst.

AA. Posterior legs without hyaline expansions.

B. Each posterior leg ending in a conspicuous claw.

C. Claw toothed near its base.

D. Body much over one-half as broad as long.*T. floricolus* C. & F.

DD. Body not over one-half as broad as long..*T. brevipes* S. & L.

CC. Claws without tooth.

D. Large second segment of posterior leg with a spur, or tooth-like expansion on inside toward base.....*T. anamas* Tyr.

DD. Large second segment of posterior leg without spur-like expansion on inside.

E. Third segment of posterior leg broader than long.

F. Claw of leg IV about twice as long as distal segment .....*T. chianaspivorus* Ewing.

FF. Claw of leg IV not longer than distal segment .....*T. approximatus* Bks.

EE. Third segment of leg IV twice as long as broad .....*T. waitei* Bks.

BB. Claw of posterior leg reduced to a small tubercle, legs themselves very long.....*T. latus* Banks.

The Mouth-parts in the Tarsonemoidea.

The mouth-parts in the Tarsonemid mites have become consolidated to a great extent and reduced in number of segments and sclerites, and are borne by a clearly differentiated anterior region of the cephalothorax, that should be designated as the capitulum. The degree of reduction in parts and of their consolidation varies in the different species and genera.

In *Tarsonemus pallidus* Banks and in the genus *Tarsonemus* the capitulum is large and conspicuous. In this species the palpi are reduced and fused to a large extent with the capitulum yet segmentation is noted. The chelicerae are represented by a pair of needle-like structures.

In *Pediculoides ventricosus* Newport the mouth-parts are lodged in a large capitulum. The chelicerae are slender and needle-like, or setiform. The palpi are much reduced, and only a single segment is evident, which is free.

In *Pediculopsis graminum* (Reuter) the capitulum of the female is large, the chelicerae are serrate and adapted for piercing but are hardly needle-like. In this species, according to Reuter, the palpi of the female are very minute structures with two free segments. In the male the chelicerae are apparently wanting, and the palpi are represented by a single free segment. Furthermore, the capitulum in *Pediculopsis* is distinctly papilliform.

In the genus *Pigmephorus* and in all the Disparipedidae the capitulum is reduced in size and is papilliform. The mouth-parts in these groups are not necessarily equally reduced. In *Pigmephorus americanus* Banks the palpi, while not entirely free, are seen to be segments. The palpi in the Disparipedidæ show various degrees of degeneration. In *Imparipes hystricinus* Berlese, according to a figure by Paoli, the palpi have four free segments. I have examined an American species of this genus, *I. texanus* (Ckll.). It has rather long, free, laterally-situated palpi, but I can only make out three free segments

Food Plants of Tarsonemus Pallidus Banks.

The cyclamen mite, *Tarsonemus pallidus* Banks, is of late becoming of more economic importance. Moznette[2] (1917) gave three food plants for this species, which were in the rank of relative importance as follows: cyclamen, chrysanthemum and snapdragon. Records are here given for the National Museum specimens: Types from chrysanthemum, Jamaica, N. Y., by Serrine; specimens from snapdragon, Bala, Pa.; from verbena, Bloomsburg, Pa.; from cyclamen, Ithaca, N. Y., by Crosby; from cyclamen, New York City, by H. S. Adams; from cyclamen, Nahant, Mass., by T. Roland; on snapdragon, New Haven, Conn., by S. T. Bradley; on cyclamen, Hartford, Conn., by Q. S. Lowry; on geranium, Whitmarsh, Md., by Sasscer; on cyclamen, Washington, D.C.; on (?), Washington, D. C. (Number on slide is 6751); on heliotrope, Ottawa, Canada, by Fletcher.

The Feeding Habits of Pediculoides Ventricosus Newport.

Pediculoides ventricosus is well known to many entomologists because of its attack on living insects. Dr. Howard has called attention particularly to its attacks on Hymenopterous parasites. This species is the one supposed to have had a disastrous effect upon the Chalcid, *Scutellista cyanea,* at a time when it was hoped that this Hymenopteron would effectively parasitize the black scale. During the past year the writer has had this species under observation, and has noted especially its food habits.

The statement has been made that the adults upon emergence feed upon the body of the female that gave them birth. These statements are undoubtedly true for the adults were repeatedly observed under the binoculars to insert their chelicerae and feed from the juices of the gravid and frequently dead females. Males were observed to feed almost entirely upon the body of their pregnant mother. This type of parasitism might be called autophagous.

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[2]Moznette, G. F. The Cyclamen Mite. Jour Agr. Research, Vol. x, No. 8, pp. 373—390, text figs. 1—6, Pls. li—lii.

Scavenger Habits: That the females of this species (Fig. 1) may live entirely as scavengers was established by the following observation. Late in October, 1921, Mr. Bridwell, of the Bureau of Entomology, gave to the writer a dead Hymenopterous larva inclosed in a small breeding cell that had attached to it engorging females. This larva was kept in its cell and observed daily until Nov. 25. The engorging females soon became replete and gave rise to scores of adult offspring. These second generation individuals attached to the same larva and completely concealed the latter with their distending bodies. On Nov. 25, after many adults had been removed in the meantime, the cell was found to be swarming with the third generation. Thus it was shown that the female of the species may live entirely upon the dead corpses, or in other words as scavengers.

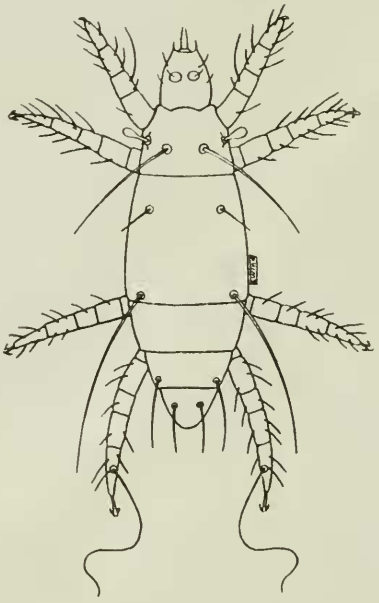

Fig. 1. *Pediculoides ventricosus*, female. (Original).

The Attacks on Man: Experimental observations made to ascertain the nature of attacks on man. Large numbers of the mites were placed; *a.*, on the upper side of the forearm, *b.*, on the side of the body, *c.*, on the tender skin inside of the bend of the elbow. In each of these cases the application ot the mites to the skin was followed by a burning sensation. There was but little itching at this time and this burning sensation soon subsided. The appearance of reddened spots, each with a small papule in the centre, was noted the day following application. These spots usually did not develop into wheals but did itch considerably. Within three days the papules were greatly reduced in size and the itching had subsided.

Do the Mites Enter Hair-follicles? On Nov. 5, females were placed on the skin separately and observed continually under the binocular for many minutes. None of these individuals entered the follicles although they were observed to occasionally investigate the mouths of the same. The width of the

female, about 0.12 mm., is greater than that of the unfilled space of most of the hair-follicles. In the case of empty follicles resulting from hair detachment, the mites are small enough to enter. The only way the mites were observed to injure man was by pricking the skin with their chelicerae. The mites never attached permanently or engorged as chiggers do.

Is Itching Due to Crushing of Mites? At 10.30 a.m. one morning many specimens in all stages were crushed on the back of the forearm. Not the least itching or injury developed. It appears, therefore, that the dermatitis that this mite causes, does not come from the crushing of the mites themselves. Just to what it is due cannot be stated at present, but the great delay in the appearance of the papules would indicate that these were not caused by the injection of a toxin.

The Transformations of Acarapis Woodi (Rennie).

Recently the writer has received from Mr. Hirst, of the British Museum, a slide of specimens of *Acarapis woodi* (Rennie), and also has had an opportunity of obtaining some live material through Mr. A. P. Sturtevant, of the Bee Culture Laboratory of the U. S. Bureau of Entomology, which material came originally from Scotland. While it is not at all the intention of the writer to make a special study of this serious parasite of the honey bee, yet it is deemed advisable to compare its different instars with those given for some of our other Tarsonemid species.

Rennie in his interesting and highly important article, "Isle of Wight Disease in Hive Bees—Acarine Disease: The Organism associated with the Disease—Tarsonemus woodi, n. sp.," gives descriptions of the following stages of the Tarsonemid of the honey bee: Ovum, larva, immature female, adult male, adult female. The "so-called" immature female is referred to in one place in Rennie's paper as the female nymph.

In the European material received the present writer does not find any such immature female, but does find a nymphal stage,—a peculiar apodous nymphal stage,— that precedes what Rennie calls the immature female. This nymph is quiescent and never is found outside of the cast larval skin.

Description of Apodous Nymph of Acarapis woodi (Rennie).

One of these apodous nymphs was dissected until it was very largely free from the containing cast larval skin, and another has been found in which the old larval skin has been almost entirely torn away in mounting. A description of the nymphal instar follows:

Apodous Nymph (Fig. 2): When first formed, oval; dimensions and general shape similar to that of engorged and quiescent larva. No legs, no mouth-parts, or any other appendages. Integument well formed, as thick as that of the larva; under low power appearing smooth but under high power seen to be minutely and indistinctly striated. Older nymphs showing, at first distinctly and later plainly, the formation of adult. Adult formed in a manner similar to that of *Pediculoides ventricosus*, the legs and chelicerae appearing first

as minute buds, which later elongate, and finally become segmented. The apodous stage is one of almost complete histolysis followed by the reformation into the adult state. Length of apodous nymph, 0.11 mm.; width, 0.06 mm.

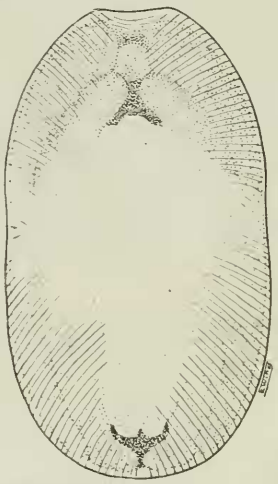

Fig. 2. Apodous nymph of *Acarapis woodi* (Rennie). Ventral view, x600. (Original).

This nymph is homologous with the apodous intrauterine nymph described by Brucker for *Pediculoides ventricosus* and with the extrauterine nymph described by Reuter for *Pediculopsis graminum*. The apodous nymph is very similar physiologically, ontogenetically and morphologically with the pupal stage of most dipterous insects. It represents undoubtedly the nymphal stage of other mites and is in fact a degeneratively and highly specialized nymph.

The Females of Acarapis Woodi (Rennie).

Rennie describes two stages for the female, the immature female and the adult female. I have failed to observe any such stages. What he figures and describes as the immature female the present writer would call the nongravid female, and what he calls the adult female (his Fig. 1) I would call the gravid female, or the ovigerous female,—the latter term having also been applied by Rennie in his formal description. These differences in the female are not fundamental, but are found in all mites, and do not represent differences due to the presence of different instars.

The Eggs of Acarapis woodi (Rennie).

The enormous size of the egg of *A. woodi* greatly impressed the writer in regard to its possible significance. A part of this significance is explained by the finding of a quiescent nymphal stage. Taking no nourishment itself this nymph must have handed on to it an added supply of potential energy. Having to supply this added energy, the larva profits greatly by receiving an added amount at time of hatching, which it gets in the form of a great amount of egg substance, which transformed into a larva produces one already almost as big as it ever gets. Rennie's figures for the dimensions of the egg are: Length, 0.14 mm.; breadth, 0.06 mm. The averages for six eggs measured by the writer are: Length, 0.127 mm.; breadth, 0.067 mm. The figures compare favorably.

The Transformations of Tarsonemid Mites.

In order to help clarify the whole matter of transformations in the Tarsonemidae a comparative study has been made of four species. The transformations of two of these have been so well worked out by two European workers, that in these two cases little will be done except to quote from their results. I have checked up both of these workers by personal studies of the species concerned.

Brucker[3] (1900) has worked out the development of *P. ventricosus* and finds that all stages are passed inside of the uterus of the female, the new and fully formed adult males and females hatching from the egg skin. The first stage of the embryo, according to Brucker, is an octopod stage with segmented appendages. Following the development of the octopod embryo, the segmental appendages become reduced in size, particularly the fourth pair of leg buds; and are curved against the ventral surface of the embryo. Brucker refers to this stage as "l'etat hexapode," notwithstanding it has eight leg appendages. Following the second embryonic stage, the substance of the appendages is absorbed and an apodous stage is reached. This stage is called the apodous pupal stage by Brucker. From this stage the adult emerges.

Reuter finds in *Pediculopsis graminum* Reuter that an octopod embryo first develops and is followed by a hexapod stage in which the fourth pair of leg buds disappear. This is the larva and is the first free-living stage. Later there forms inside of the larval stage a new skin, but with it no appendages develop. This skin Reuter calls the "apoderma" stating that it is the rudimental nymphal skin. The nymphal stage, therefore, is incomplete and is passed inside of the larval skin. From this apodous nymphal instar the adults are formed.

In this country Moznette has worked on the life history of *Tarsonemus pallidus* Banks. He made the important discovery that no free-living nymph exists. He gives the following instars, or stages, for this species: egg, larva, quiescent larva, adults. Speaking of the transformations of this species he states: "No nymphal stage was found in this species and instead of a nymph originating from a larva, as is the case in the life history of most mites, a larva transforms to a quiescent stage, which later gives rise to the adult form." The present writer has received from Moznette a slide of *T. pallidus* in which is found a quiescent larva, within which is a fully formed adult female. I have also observed an abundance of other material of this species and find that the adult mentioned by Moznette is contained, not in the old larva skin, but in an apodous skin inside of the old larval integument. In a specimen received by Moznette a rupture of the old cast larval skin at one end of the body reveals very clearly this latter apodous instar. Further it is noted that the new legs of the first three pairs are formed, not inside of the skins of the larval legs as they are when a legged nymphal stage follows the larval stage, but inside another apodous envelope. This apodous envelope is no other than the skin of an apodous nymphal stage.

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[3]Brucker, E .A.—Monographie de *Pediculoides ventricosus* Newport et Theorie des Pieces buccales des Acariens. Thesis presentées a la Faculté des Sciences des Paris, pp. 355—442, text figs. 1—12, Pls. xviii—xxi.

and it is undoubtedly the same stage as is represented by the apodous nymph of *Pediculoides ventricosus* and *P. graminum*.

When we compare the transformations of these other Tarsonemid mites with those of *T. woodi*, we can interpret those of the latter in a new light. It is observed that the transformations of *T. woodi* are similar to those of the other species here considered, although the morphology of the instars is different, and undoubtedly its life history will be found also quite different. Here is given an annotated chart illustrating by way of comparison the different instars of the four

	EGGS	LARVA	NYMPH	ADULT
Pediculoides ventricosus	Many produced: never laid; about the same size as newly emerged ♀.	Represented by octopod deutovum stage of embryo; no true larva existing.	Represented by apodous intrauterine "pupe", which is really a nymph.	Not degenerate in any way. Facultative predators, scavengers or parasites.
Pediculopsis graminum	Many produced: about two-thirds the size of newly emerged ♀.	Normal, free-living.	Represented by apodous nymph found inside of old larval skin.	Not degenerate; free, sucking juices of plants.
Tarsonemus pallidus	About one-third as large as newly emerged female: is laid.	Normal, free-living.	Represented by apodous nymph formed inside of larval skin.	Normal, not degenerate; sucks juices of plants.
Acarapis woodi	A very large egg, about the size of nongravid female: laid in tracheae of honey bee.	Free-living but degenerate. Two pairs of legs represented by stumps.	Represented by apodous nymph formed inside of old extra-uterine larval skin.	Parasitic (free-living?); female somewhat degenerate.

species considered, the comparable, or homologous instars being placed in vertical columns.

Degeneration and Adaptation in Parasitic Species.

In *Pediculoides ventricosus* Newport there has been apparently no degeneration, but on the contrary, in regard to reproduction at least, there has been great specialization. This specialization has brought about a tremendous increase in the fecundity of the female and is doubtless correlated with the precarious conditions that exist in regard to transferance to new hosts. Of those females that are compelled to leave their mother and search out a new host undoubtedly the vast majority must perish. It is seen that the successful female, having once reached a proper host has an abundance of food, hence she can meet the enormous drain placed upon her because of her great reproductive powers. This reproductive power which brings about the swelling of her body during pregnancy to many times its original size, incapacitates her for locomotion, but only, it is noted, after she has reached her host.

In *Acarapis woodi* degenerative changes have already been noted by Rennie in the shortening of the posterior legs. This species also shows other evidences of degeneration. The second and third pairs of legs of the larva are not only reduced, but exist practically as vestiges. These legs in the free-living species are usually equal to the front pair and are efficiently functional. The sense

organs, called pseudostigmatic organs, which are so conspicuous and characteristic of the females in the Tarsonemidae are lost in the honey bee Tarsonemid, as was noticed by Rennie. In the male there is little evidence of degeneration. The posterior legs are far from being as well developed as they are in many species, yet are about as large relatively as they are in some free-living forms.

All of these degenerative changes observed in *A. woodi* are most easily explained by attributing them to adaptation to a parasitic life. Other structures also indicate a form of adaptation that the writer has found[4] to be general in the parasitic Acarina. This is the development of extraordinarily large setae. The female of *A. woodi,* not only has all the body setae well developed, but two of these located on each of the stumpy, degenerate hind legs are enormous, and in length are about equal to the total length of the body. In regard to the male of *A. woodi* but little specialization is seen in this respect.

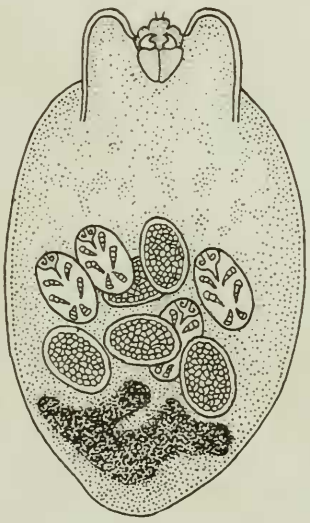

Fig. 3. Ventral view of adult female of *Podapolipus reconditus* R. & G. (After Rovelli and Grassi).

In the parasitic family Disparipedidae both degeneration and adaptation are pronounced. Of the degenerative changes the most pronounced is the shortening of the legs. These may be reduced to mere stumps. It is particularly interesting to note that in this parasitic family the stumpy posterior legs of the female almost invariably have enormous setae as has been observed in the female of *A. woodi.*

The limit of degeneration in the Tarsonemidae, and for that matter for all the Acarina, is found in the genus *Podapolipus* Rovelli and Grassi. In this genus the female (Fig. 3), which is at first hexapod, upon reaching maturity is legless. The male is hexapod. These most degenerate Tarsonemids are found under the elytra of certain Old World beetles.

[4]Ewing, H. E. (1911). The Origin and Significance of Parasitism in the Acarina. Trans. Acad. Sci. St. Louis, Vol. xxi, pp. 11—70, Pls. i—vi (Particular reference, p. 52).